REMINISCING HIMALAYAN GLACIERS

Glaciology Division
Geological Survey of India
Northern Region, Lucknow

2020

Hamtah Glacier Camp, Lahaul and Spiti District, Himachal Pradesh
(Photo Credit : Kalyan Krishna, 2016)

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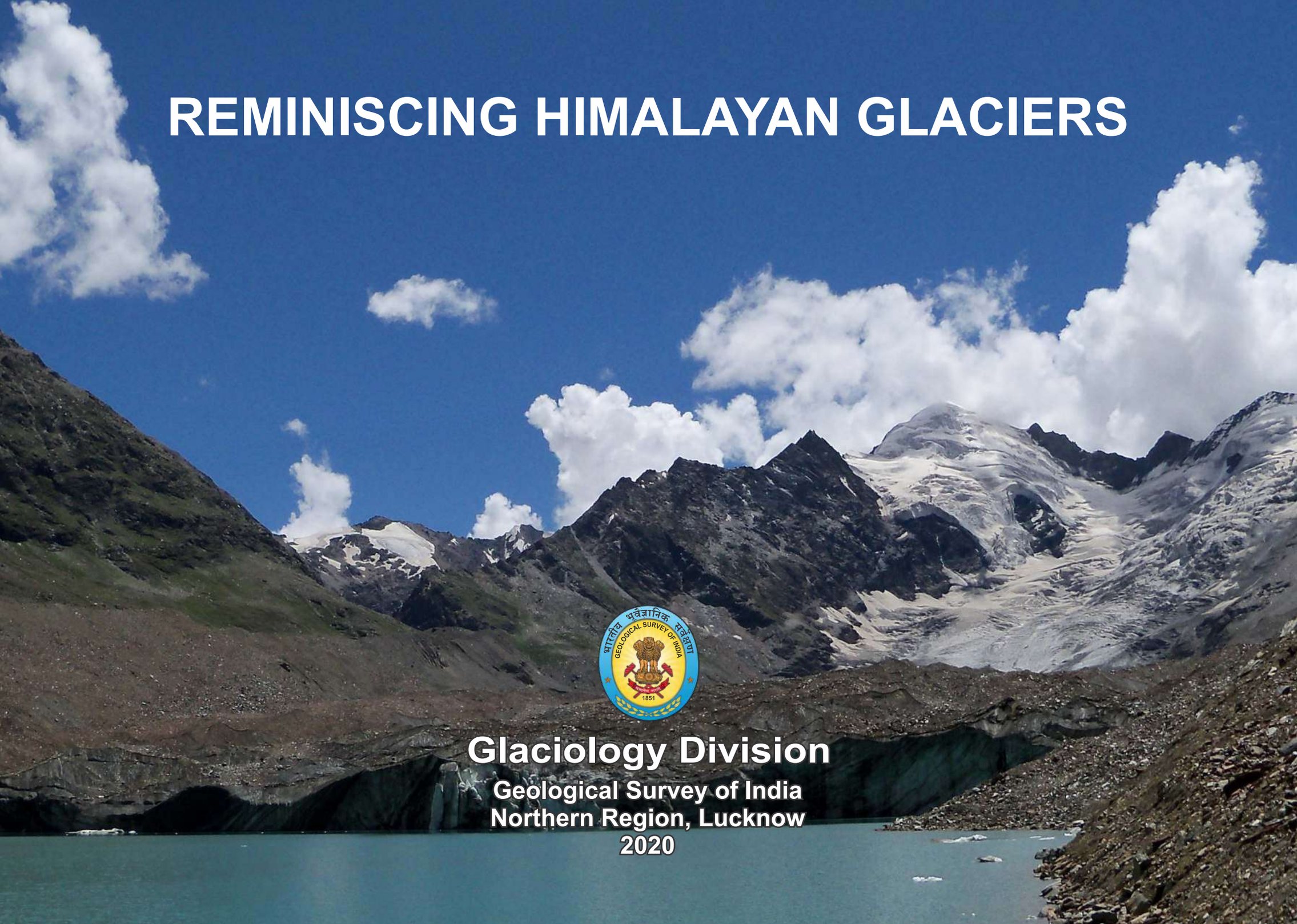

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Authors :

Rajesh Asthana, Deputy Director General
S.P. Shukla, Director
Rakesh Mishra, Superintending Geologist
Kalyan Krishna, Senior Geologist

Printing and Processing:

Champa Sensarma, Director
Sana Naqvi, Senior Geologist
Publication Division, Northern Region
Geological Survey of India, Lucknow

Under overall guidance :

Shri Som Nath Chandel
Additional Director General & HoD
Geological Survey of India, Northern Region, Lucknow

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Title Page : Gepang Gath Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit : Muneer A. Mukhtar, 2013)
Back Cover : Kettle Lake, Rangdo Valley, Ladakh (Photo Credit : Zahid Majeed, 2019)

Parang Glacier, Spiti Valley, Himachal Pradesh
(Photo Credit: Arun Chaturvedi, 2013)

Foreword

Glaciers are important source of fresh water stored in solid state for which glaciated regime of Himalayan region is also known as Water Tower of Asia. The major rivers flowing through the northern states of India owe their origin to the glaciers in the mighty Indian Himalaya. In addition to being the reservoirs of fresh water, these glaciers are storehouse of various picturesque landforms distributed all over the Himalaya. These glaciers are also considered as proxy records of climate change.

Keeping these in view, Geological Survey of India had created a specialised 'Glaciology Division' way back in 1974. Since then studies on mass balance, secular movement, snow cover assessment and Glacial Lake Out Burst Flood (GLOF) studies are being regularly undertaken by GSI. GSI has a vast collection of photographs and maps of the glaciers and landforms resulted from various expeditions in the remote corners of the mighty Himalayas. The present coffee table book REMINISCING HIMALYAN GLACIERS is an attempt by the officers of GSI to showcase the glimpse of fascinating Himalayan glaciers.

I am confident that the present coffee table book will not only be a first hand guide to the Himalayan glaciers, but also help in inspiring one and all for taking further keen interest in cryosphere of Himalayan region.

(M. Sridhar)
Director General

Rassa Group of glaciers, Karakoram Range, Ladakh
(Photo Credit: Zahid Majeed, 2019)

Preface

India has been bestowed upon by vast resource of freshwater including large number of glaciers and perennial snow cover. The glaciers are not only vast resources of fresh water but also act as one of the most vital agency responsible for scenic landscape of the mighty Himalaya.

During the second half of nineteenth century, after its inception in 1851, the geoscientists of Geological Survey of India studied several glaciers, notable among them are W. Theobold who in 1874 investigated seven glaciers in the Northwestern Himalayas. W.T. Blanford published "Notes on glaciers in Hindustan" in 1873 and "Notes on age and ancient glaciers of the Himalaya" in 1891. Gangotri Glacier snout was sketched by Griesbach in 1889. Similarly, P.N. Bose in 1890 visited Kapru and Pandim glaciers in Sikkim. R. D. Oldham had published "Note on ground ice" in 1894.

During International Geophysical Year (1957-58) followed by International Hydrological Decade (1965-74), which counted itself into a continuous International Hydrological Programme saw another concerted International/ National effort towards glaciological studies in modern form. With the inception of Glaciology Division on 4th January 1974, GSI initiated studies on snow, ice and glacier with modern approach.

Systematic glaciological studies in Geological Survey of India conducted during the last four decades can be broadly classified in four categories viz. assessment of glacier resources, water resource management, climate variability and other associated studies including depth assessment, lichenometry, artificial augmentation of melting of glaciers, geochronology and Glacial Lake Out Burst Flood (GLOF) studies.

The present coffee table book is prepared to showcase the evolution of glaciological studies in GSI, besides providing an opportunity of briefly perceiving the fascinating glacial landforms of Indian Himalaya. I am sure that the readers will be spellbound with the glimpses of unseen fascinating landforms carved out by glaciers of the Himalaya.

(Som Nath Chandel)
Additional Director General

Thara Kangri Glacier, Karakoram Range, Ladakh
(Photo Credit: Zahid Majeed, 2019)

Outline

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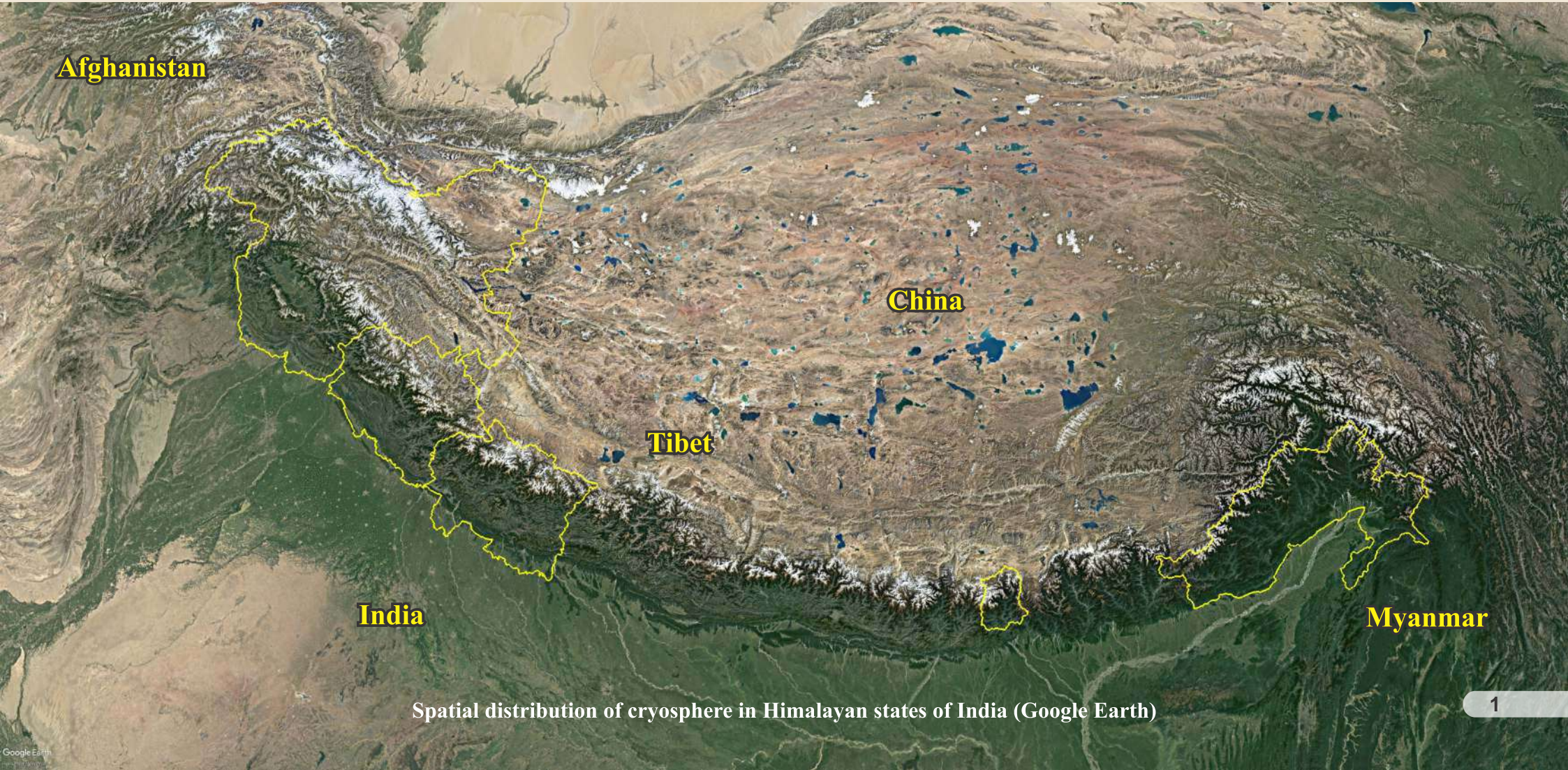
Glacial Horn in the background of Tharang Glacier, Miyar Valley, Himachal Pradesh
(Photo Credit: Rajesh Asthana, 2017)

Parkachik Glacier, Zanskar Valley, Ladakh
(Photo Credit: Pawan Kumar, 2015)

Introduction

Himalaya, the '*Abode of Snow*' derives its name from Sanskrit and has always fascinated the mankind. Himalayan ranges are spread across several countries from Afghanistan in the west to Myanmar in the east. Mount Everest is the highest peak located in Nepal Himalaya.

Glaciers are mass of ice formed due to the accumulation of snow at the head that flows slowly down slope under the influence of gravity. As per 'Climate Change in Mountain Ecosystems Program, USGS' minimum size of a glacier should be 0 .1 sq km.



Spatial distribution of cryosphere in Himalayan states of India (Google Earth)

The glaciers and snow-cover which create the Himalayan cryosphere is not only admired for its beauty, but also the key to the fresh water availability for the human population settled in the downstream regions. In addition to this, the Himalayan cryosphere also affects the overall monsoon patterns, which is the lifeline of the entire subcontinent. In India, the glaciers are restricted to the extra-peninsular area, *i.e.* the Himalayas within the latitude 27º N to 36ºN and longitude 72ºE to 96º E (Raina and Srivastava, 2008).

The dynamic nature of glaciers and their interaction with other elements of the earth's system *i.e.* atmosphere, geosphere, cryosphere and biosphere produces large changes in the ecosystem.

Durung Drung Glacier, Zanskar Valley, Ladakh
(Photo Credit : Muneer A. Mukhtar, 2013)

Glaciers Resources of Indian Himalaya

The Indian Himalaya has been bestowed upon by vast resource of freshwater including large number of glaciers and perennial snow cover. All the major north Indian rivers owe their origin to thousands of glaciers in mighty Himalayas that houses the largest reserves of snow, ice and glaciers outside the polar region.

As per the glacier inventory, Indian part of Himalaya contains 9575 glaciers. Besides, thousands of square kilometers of the Himalaya comes under seasonal snow cover during winters. Thus, the Himalayan cryosphere constitutes the most important source of fresh water (Updated Edition, Spl. Pub. 34, GSI, 2009).

Inventory Status	Indus Basin	No. of Glaciers	Ganga Basin	No. of Glaciers
Detailed Inventory (Level 3&4)	Ravi	172	Yamuna	52
	Chenab	1278	Bhagirathi	238
	Jhelum	133	Alaknanda	407
	Beas	277	Ghaghra	271
	Satluj	926	Tista	449
	Indus	1796	Brahmaputra	161
	Shyok	2658		
	Kishanganga	222		
Regional Assessment (Level 1)	Gilgit	535		
Total		7997		1578
Grand Total				9575

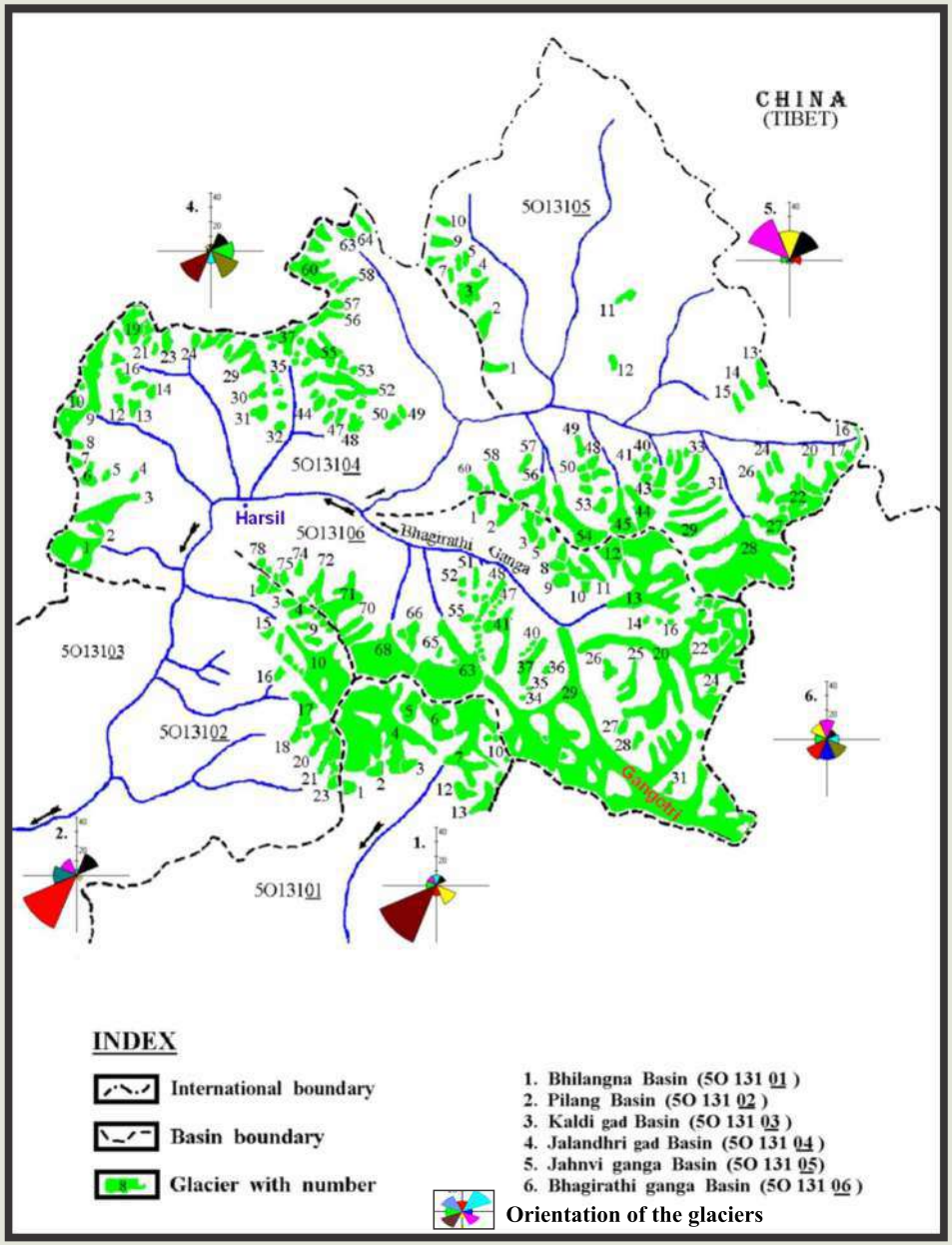
Panchi *Nala* - 1 Glacier,
Lahaul & Spiti District, Himachal Pradesh
(Photo Credit : Kalyan Krishna, 2019)

Bhagirathi Basin 5O131

The Catchment

The Bhagirathi Basin is bounded by long. 78°15′00″E and 79°20′00″ E, and lat. 30°07′00″N and 31°15′00″N. The basin is defined in the north by the international boundary, and by the water divide between Satluj and Bhagirathi basins. In the south, Devprayag (the confluence of Alaknanda River and Bhagirathi River) marks the limit of the basin. The basin limits are marked by the water divide between Bhilangna Ganga (a tributary of Bhagirathi River) and Mandakini River (tributary of Alaknanda River) in the east, and water divide with the Yamuna Basin in the west. Bhagirathi Basin is a IVth order basin and has been further divided into six Vth order basins:

S. No.	V Order Basins	Code	Status
1.	Bhilangna Ganga	5O131 01	Glacierised
2.	Pilang	5O131 02	Glacierised
3.	Kaldi	5O131 03	Non-glacierised
4.	Jalandhri *Gad*	5O131 04	Glacierised
5.	Jahnvi Ganga	5O131 05	Glacierised
6.	Bhagirathi Ganga	5O131 06	Glacierised



Glacier Inventory Map of Bhagirathi Basin, Uttarakhand
(Updated Edition, Spl. Pub. 34, GSI, 2009)

Distribution of Glaciers

Indian Himalayan glaciers are distributed from Karakoram in northwest (Jammu & Kashmir) to Arunachal Himalayas in the northeast (Arunachal Pradesh).

Sagtogpa East Glacier, Rongdo Valley, Ladakh
(Photo Credit: Muneer A. Mukhtar, 2018)

Zemu Glacier, Tista Valley, Sikkim is the largest glacier of Zemu Basin which is northern most glacier bearing basin of the Sikkim Himalaya and is located at the base of the mountains supporting Kanchenjunga. It occupies an area of 1992.74 sq km. The basin is drained by two major tributaries the Zema Chu and the Hema Chu. (Photo Credit: Murali Mohan, 2012)

Bara Shigri Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Zahid Majeed, 2015)

Beginning of Glaciological Investigations

Sketch of Gangotri Glacier snout, (Griesbach, C. L. 1891)

Records available in the gazetteers of the erstwhile states during the British India provide some brief information on Himalayan glaciers and snow.

Glaciological studies in Himalaya were initiated way back in 1840 by demarcating the snow line.

During seventies and eighties of nineteenth century, lot of activities were observed by the geologists of Geological Survey of India. These include:-

- In 1874, W. Theobold investigated seven glaciers in the Northwestern Himalaya.
- W. T. Blanford, published 'Note on glaciers in Hindustan' and another 'Note on the age of ancient glaciers of the Himalayas' in 1873 and 1891 respectively.
- Gangotri Glacier snout was sketched by C. L. Griesbach in 1891.
- In 1890, P.N. Bose visited in glaciers of the Kapru and Pandim in Sikkim.
- R. D. Oldham published "Note on ground ice" in 1894.

- In 1894, the Council of the sixth International Geological Congress in Zurich, Switzerland decided to create an International Glacier Commission (Commission Internationale des Glaciers, C.I.G.) with the task of 'inciting and spreading the studies of changes in the sizes of glaciers.'
- In 1905, D. W. Freshfield on behalf of the "Commission International des Glacier" drew the attention towards the importance of determining the secular movements of the principal Himalayan glaciers.
- The sub-committee of Board of Scientific Advisory to the Government of India, comprising Col. F.B. Longe R.E. Surveyor General, Dr. G. T. Walker and Sir T. H. Holland formulated the system of observations, distribution of necessary information and collection of data under the aegis of Geological Survey of India.
- In 1906, twelve principal glaciers in Kumaon, Lahaul and Kashmir region were surveyed.
- Later glaciological studies were taken up in Dhauli and Lissar Valley in erstwhile Uttar Pradesh by Grinlinton and Alukthang; Guicha and Zemu glaciers in Sikkim by La Touche.
- Gilbert studied the snout of the Arwa Valley glaciers in erstwhile Uttar Pradesh in 1934. The glaciers of the Karakoram were studied by K. Mason in 1930. Auden mapped the snout of the Gangotri Glacier in 1935.

Snout of Bara Shigri Glacier
(Photo Credit: Pascoe, 1906)

Snout of Milam Glacier
(Photo Credit: Cotter, 1906)

Snout of Sona Pani Glacier
(Photo Credit: Walker, 1906)

- During the International Geophysical Year (1956) the study of the glaciers got a fresh impetus and simultaneous monitoring of some of the glaciers were carried out by the Geological Survey of India. The intervening period between International Geophysical Year (IGY) and International Hydrological Decade (IHD) also documented some of the glaciers.
- In 1971, the first training cum study expedition was launched to Gangotri Glacier under the leadership of the GSI.
- In 1973, a multi-disciplinary expedition to Gara Glacier, Himachal Pradesh was launched by the Geological Survey of India. This expedition paved the way for the creation of the full-fledged division in Geological Survey of India.
- On 4th January 1974, 'Snow, Ice and Glacier Division' was created in Geological Survey of India. Later the division was re-christened as the Glaciology Division.
- Since 1974, Geological Survey of India is continuing its journey in the field of glaciology.

Gara Glacier in 1979 (Photo Credit: M.K. Kaul)

Gara Glacier in 2011 (Photo Credit: Om Prakash)

Himalayan Glacial Features and Landforms

Himalayan glaciers typically expose a variety of Alpine type glacial features. These glaciers are formed in high mountainous regions. Usually, a glacier is divided in two zones, accumulation and ablation. Accumulation zone is situated at the head of the glacier while the ablation zone, in the down stream, is delimited by snout. Glacial processes involve all the phenomena that operate from the bergschrund to the snout of the glacier. The interaction of these processes with the bed rock and valley wall produces different glacial landforms.

U-shaped Rangdo Valley, Ladakh
(Photo Credit: Zahid Majeed, 2018)

Suru River at the bottom of the photo, originating from Suru basin glaciers is flowing from right to left. Note the Kargil Town located on reworked moraines and debris situated at the right bank with Zanskar Range in the background. (Photo Credit: Zahid Majeed, 2014)

U-shaped valley is formed by glacial erosion on way to Amarnath Cave, Ganderbal District, Jammu and Kashmir. (Photo Credit: S. Mukerji,1982)

U-shaped Miyar Valley, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2018)

U-shaped Rangdo Valley, Ladakh
(Photo Credit: Zahid Majeed, 2018)

Milam Glacier, a typical example of an ice stream flowing within a well-defined valley glacier, Pithoragarh District, Uttarakhand. These glaciers are characteristically longer than width. (Photo Credit: Rakesh Mishra, 2011)

Bergschrund, at the head of Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh is a very deep and wide crevasse opening which opens in summer near the top of the neve field of a cirque, where the head of a glacier is pulled away from the precipitous walls or from ice adhering to them. (Photo Credit: S.P. Shukla, 2014)

Accumulation zone of a glacier in Chandra Valley, Lahaul & Spiti District, Himachal Pradesh, is part of a glacier, that turns into firn and then glacier ice over a period of several years. (Photo Credit: S.P. Shukla, 2006)

Bergschrund of Panchi *Nala-II* Glacier
(Photo Credit : Pawan Kumar, 2019)

Active rock glaciers are defined as lobate and tongue-shaped bodies of frozen debris, which move down slope or down valley with a velocity of a few centimeters or up to some decimeter per year. Rock glacier in Bhaga Valley, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: S.P. Shukla, 2007)

Hanging Valley: Miyar Valley, Lahaul and Spiti District, Himachal Pradesh
(Photo Credit: Rakesh Mishra, 2018)

Cirque Glacier - near Hamtah Pass, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Pawan Kumar, 2014)

Transverse crevasse - a close up view, Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2016)

Crevasses are gaping fissures formed during flow of glacier ice when the ice becomes overstrained and gives way by stretching. The crevasses could be longitudinal (parallel to the glacier) or transverse (across the glacier) depending upon the stress conditions.

Crevasses in Glacier No. 30, Kullu District, Himachal Pradesh
(Photo Credit: S.S. Dutta, 2003)

Snout of Samudra Tapu Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Muneer A. Mukhtar, 2013)
Snout is the frontal/terminal part of the glacier. It is partly exposed as bare ice and partly covered under morainic material. The snout front exposes one or more openings through which glacier melt streams emerges. These openings are known as ice caves.

Snout of Gapang Gath Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Muneer A. Mukhtar, 2012)

Kedar Tal, Uttarkashi District, Uttarakhand - Lake formed between lateral moraines of Kedar Bamak and tributary glacier.
(Photo Credit: Murali Mohan, 2016)

Supra-glacial lake, Dunagiri Glacier, Chamoli District, Uttarakhand. (Photo Credit: S. Mukerji, 1984)

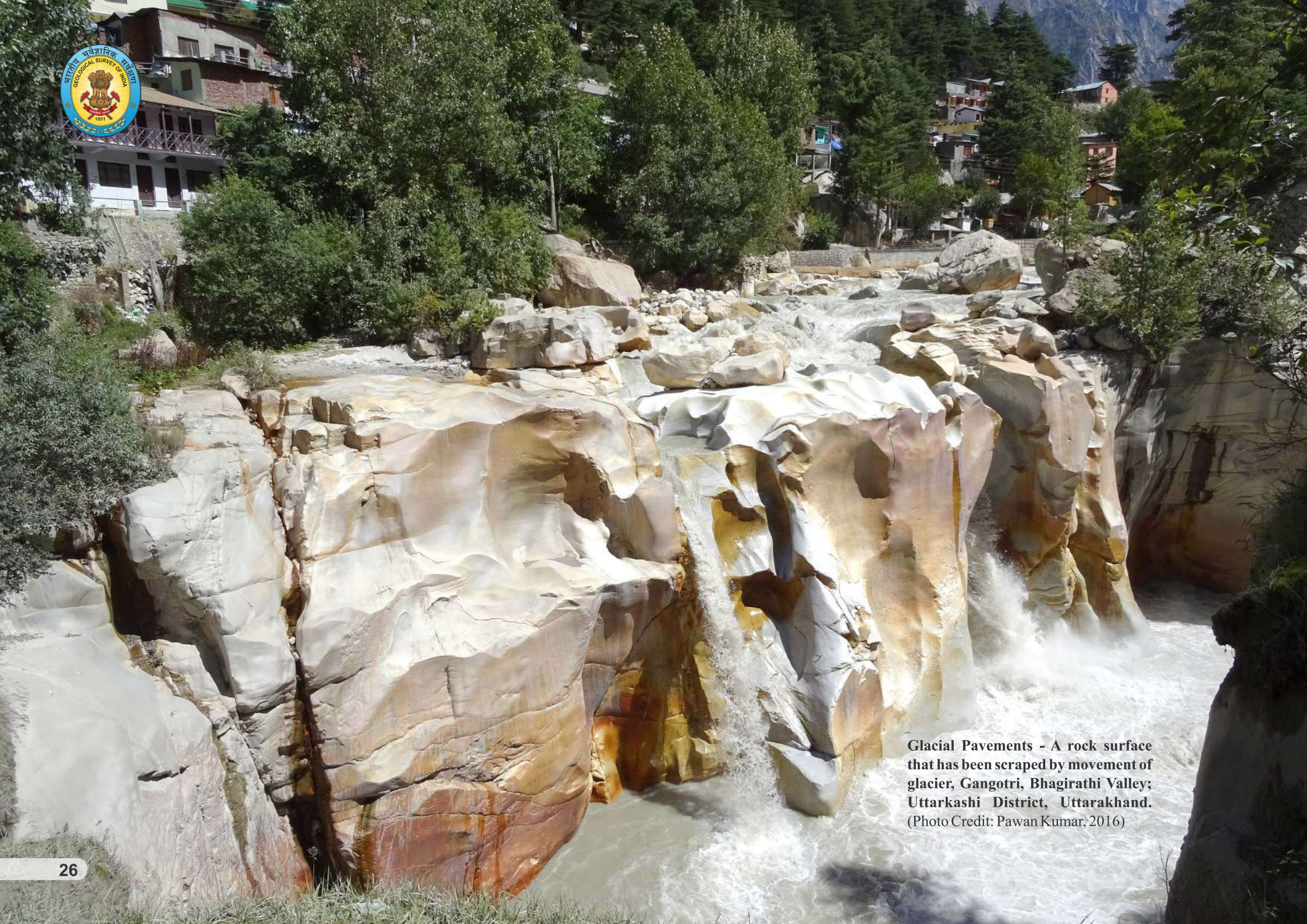
Supra-glacial lake, Milam Glacier, Pithoragarh District, Uttarakhand. (Photo Credit: Muneer A Mukhtar, 2011)

Serrac face and supra-glacial lake, Panchi *Nala*-II Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: S.P. Shukla, 2007)

Supra-glacial channel in the higher reaches, Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Abhinandan Srivastava, 2008)

Moulins (openings in the glacier ice formed due to supra-glacial and englacial streams on or within the glacier), Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Arun Chaturvedi, 2012)

Rock polishing and striations due to glacial abrasion, Bhaga Valley, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: S.P. Shukla, 2006)



Glacial Pavements - A rock surface that has been scraped by movement of glacier, Gangotri, Bhagirathi Valley; Uttarkashi District, Uttarakhand. (Photo Credit: Pawan Kumar, 2016)

Outwash plain of Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: S.S. Dutta, 2008)

Supra-glacial moraine and lateral moraine of Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: Ajai Kumar, 2009)

Recessional (terminal) moraine, Uldhampu Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2017)

Recessional (terminal) moraine, Panchi *Nala*-I Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Pawan Kumar, 2019)

Lateral moraine, Gangstang Glacier, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: S.P. Shukla, 2008)

Ablation zone of Zemu Glacier with both right and left lateral moraines, North Sikkim District, Sikkim.
(Photo Credit: S.P. Shukla, 2012)

Ice cored moraine (remnant ice in the core of moraine), Yoche Lungpa Valley, a tributary of Bhaga River, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: S.P. Shukla, 2006)

Earth pillars formed due to differential erosion of moraines, near Mabang Glacier, Uttarakhand.
(Photo Credit: Pawan Kumar, 2017)

Earth Pillars, Dhauliganga Valley, Pithoragarh District of Uttarakhand
(Photo credit : Pawan Kumar, 2016)

Drumlins in Miyar Valley, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2017)

En-glacial debris, Miyar Glacier, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: Kalyan Krishna, 2017)

Glacial sole, Miyar Glacier, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: Kalyan Krishna, 2017)

Kame terrace, Miyar Valley, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: Pawan Kumar, 2018)

Series of dirt cones at Hamtah Glacier, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2016)

Glaciological Studies in Geological Survey of India

Bara Shigri Glacier, Himachal Pradesh
(Photo Credit: Pawan Kumar, 2015)

Glaciers and Climate

Climate change includes changes in regional climate characteristics, like temperature, humidity, rainfall, wind, and severe weather events lasting for an extended period (decades or longer). The sensitivity of the glaciers and their wide-spread distribution in space makes them most suitable proxy records of climate change and acting as thermometers of climatic changes.

In order to assess the impact of climate change on glacier, Geological Survey of India has conducted studies by using ground based surveys including physically mapping the snout front of the glacier from fixed stations using standard surveying techniques and comparing them with the available baseline data including Survey of India toposheets, aerial photographs, satellite data and previously surveyed maps. Glacier mass balance studies have been conducted on Rulung, Neh Nar, Gara, Gor Garang, Shaune Garang, Tipra Bank, Dunagiri, Changme Khangpu and Hamtah glaciers .

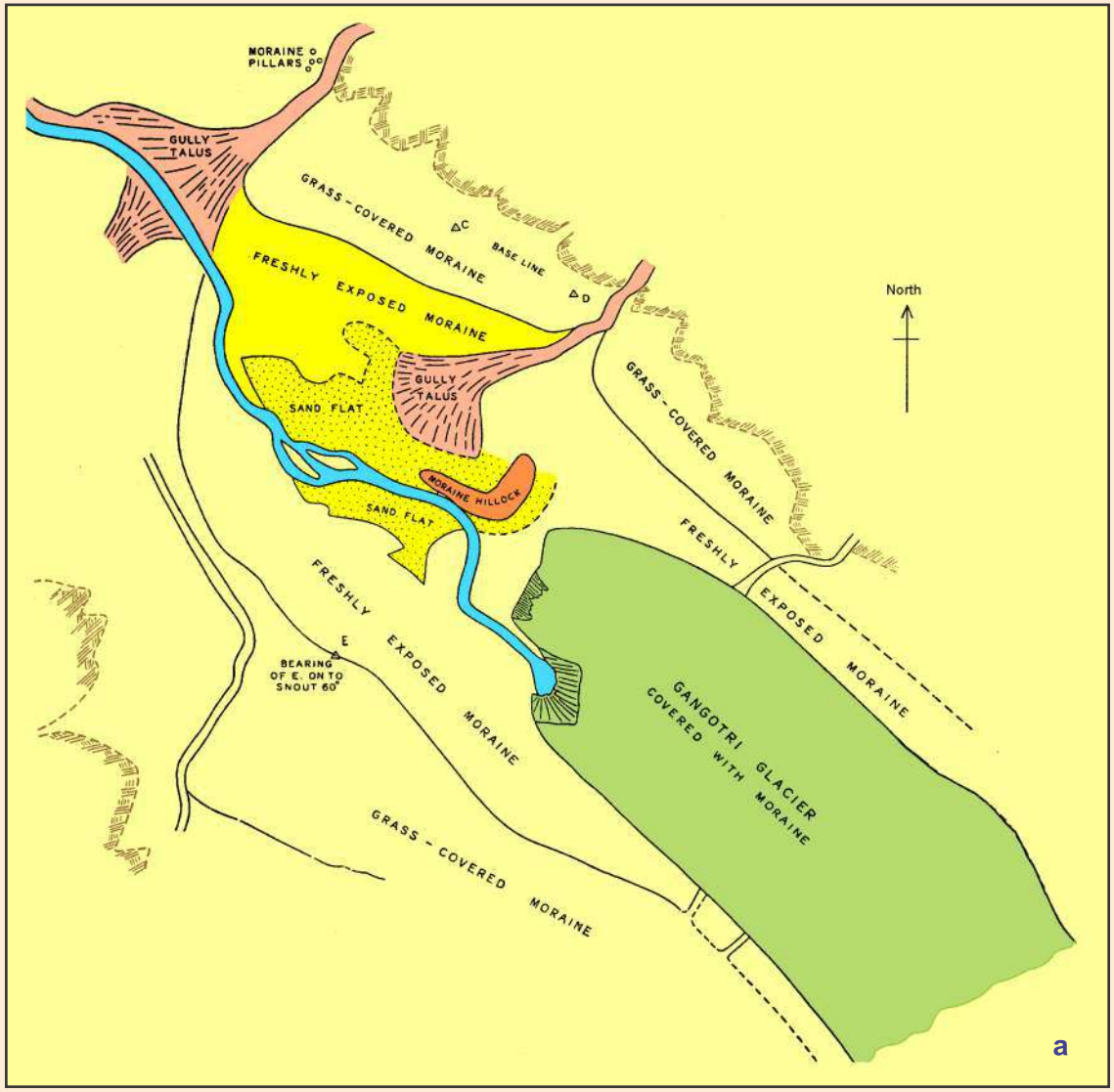
Glacier table, Hamtah Glacier, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2015)

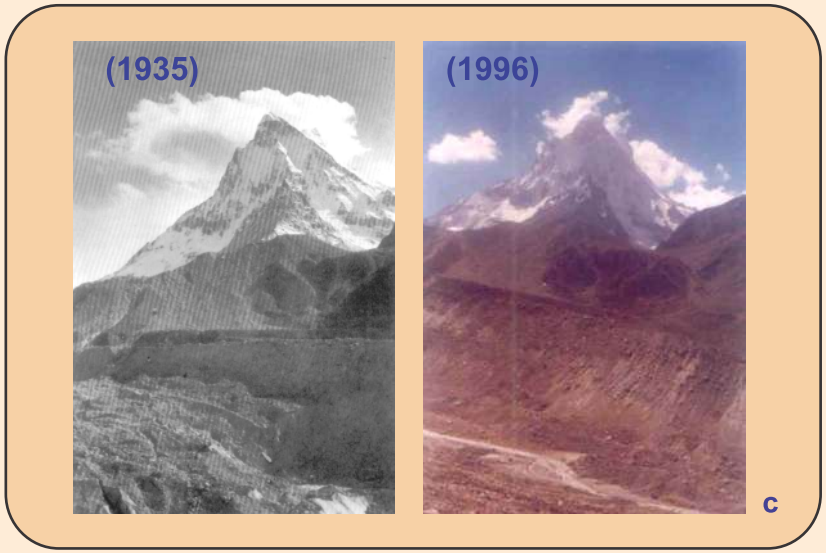
Glaciological Studies in Geological Survey of India

- Glacier Resource Assessment
- Glacier Regimen Studies
- Glaciers & Climate Variability Studies
- Societal & Other Studies
- HRD and Data Dissemination

Geomorphological Mapping
Stake Monitoring
Hydrometry Studies
OSL Sampling
Accumulation Studies
Snout Mapping

Gangotri Glacier





(a) Snout of Gangotri Glacier, Uttarkashi District, Uttarakhand, sketch map prepared by Auden in 1935 (Digitised and coloured by S. P. Shukla).
(b) Snout of Gangotri Glacier, Uttarkashi District, Uttarakhand in 1971 (Photo Credit: C.P. Vohra), **and**
(c) Retreat of Gangotri Snout between 1935 and 1996 (Photo Credit: J.B. Auden & C.V. Sangewar)

Photo mosaic of the pro-glacial region of Gangotri Glacier showing position of the ice caves during 1862-1971 period.
(Photo Credit: C. P. Vohra, 1971)

Snout of Gangotri Glacier
(Photo Credit: U. K. Bassi, 1976)

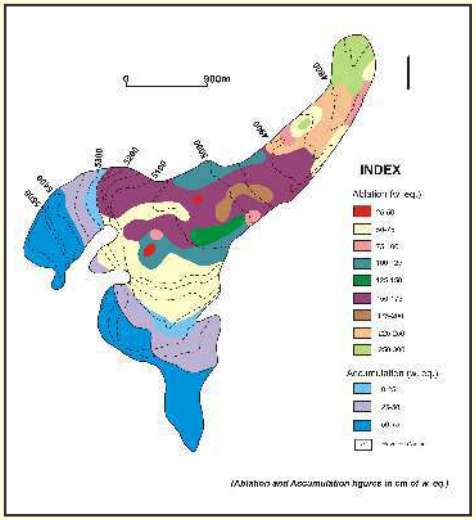
Snout of Gangotri Glacier
(Photo Credit: V. M. K. Puri, 1990)

Snout of Gangotri Glacier
(Photo Credit: C. V. Sangewar, 1996)

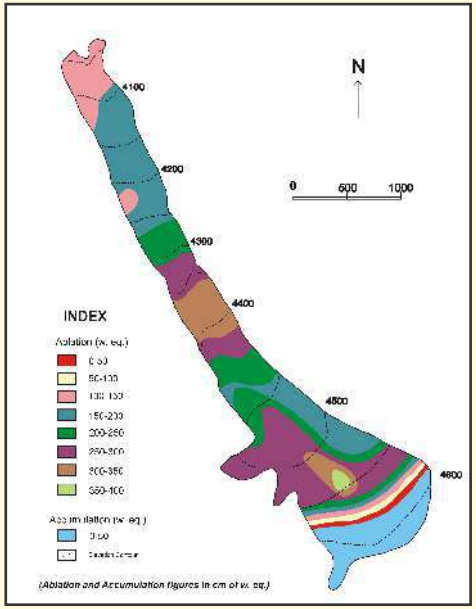
Glacier Mass Balance Studies

Gara Glacier, Himachal Pradesh (Photo Credit: Saleesh P.N., 2010)

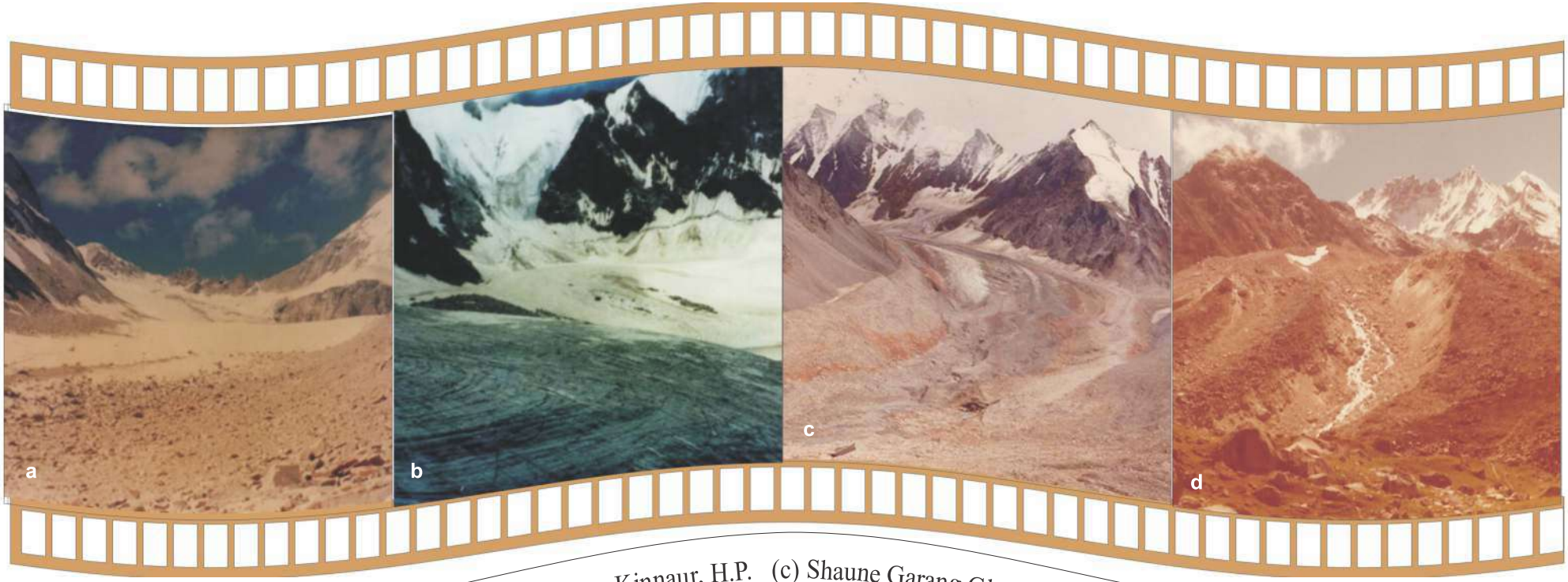
Hamtah Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: Suhrit Pramanik, 2016)



(b) Mass balance map, Gara Glacier



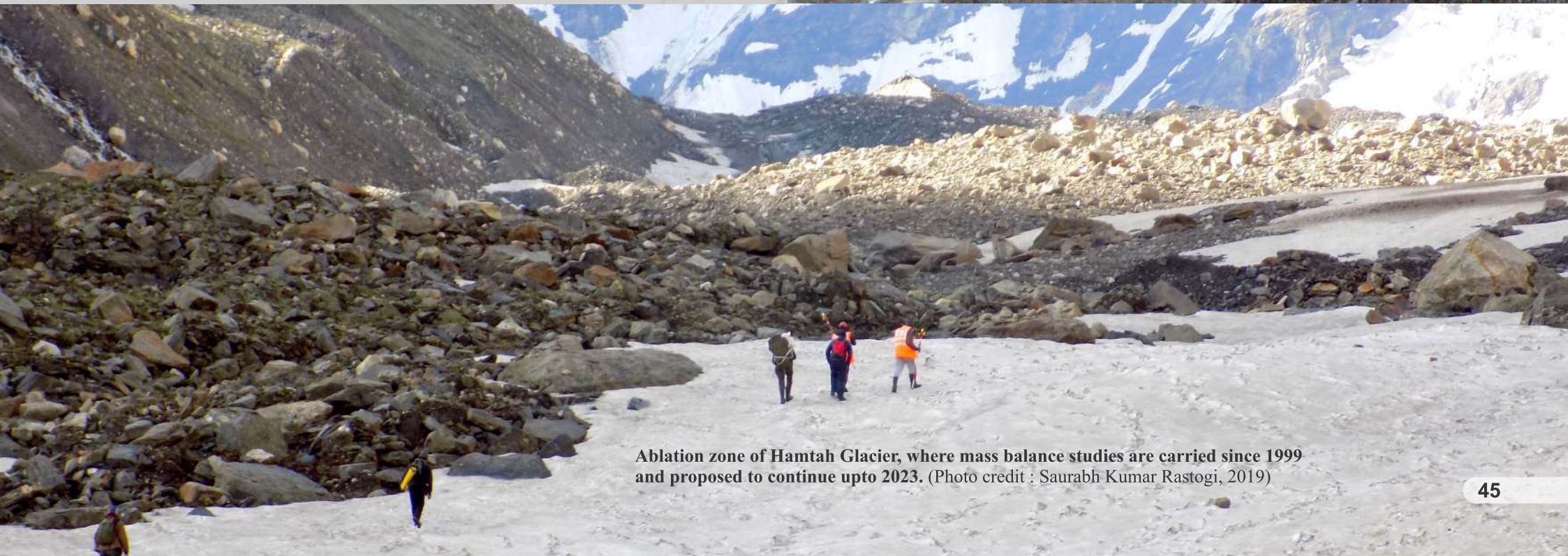
(d) Mass balance map, Hamtah Glacier



(a) Gara Glacier, Kinnaur, H.P. (b) Gor Garang Glacier, Kinnaur, H.P. (c) Shaune Garang Glacier, Kinnaur, H.P. (d) Dunagiri Glacier, Uttarakhand

Gara Glacier, Kinnaur District, Himachal Pradesh, The first glacier on which mass balance studies were initiated in 1974.

Neh Nar Glacier, Ganderbal District, J&K; Mass balance studies in 1974-85 indicated negative mass balance of 4.67 m w. eq. (Photo Credit: N.K. Agarwal, 1984)



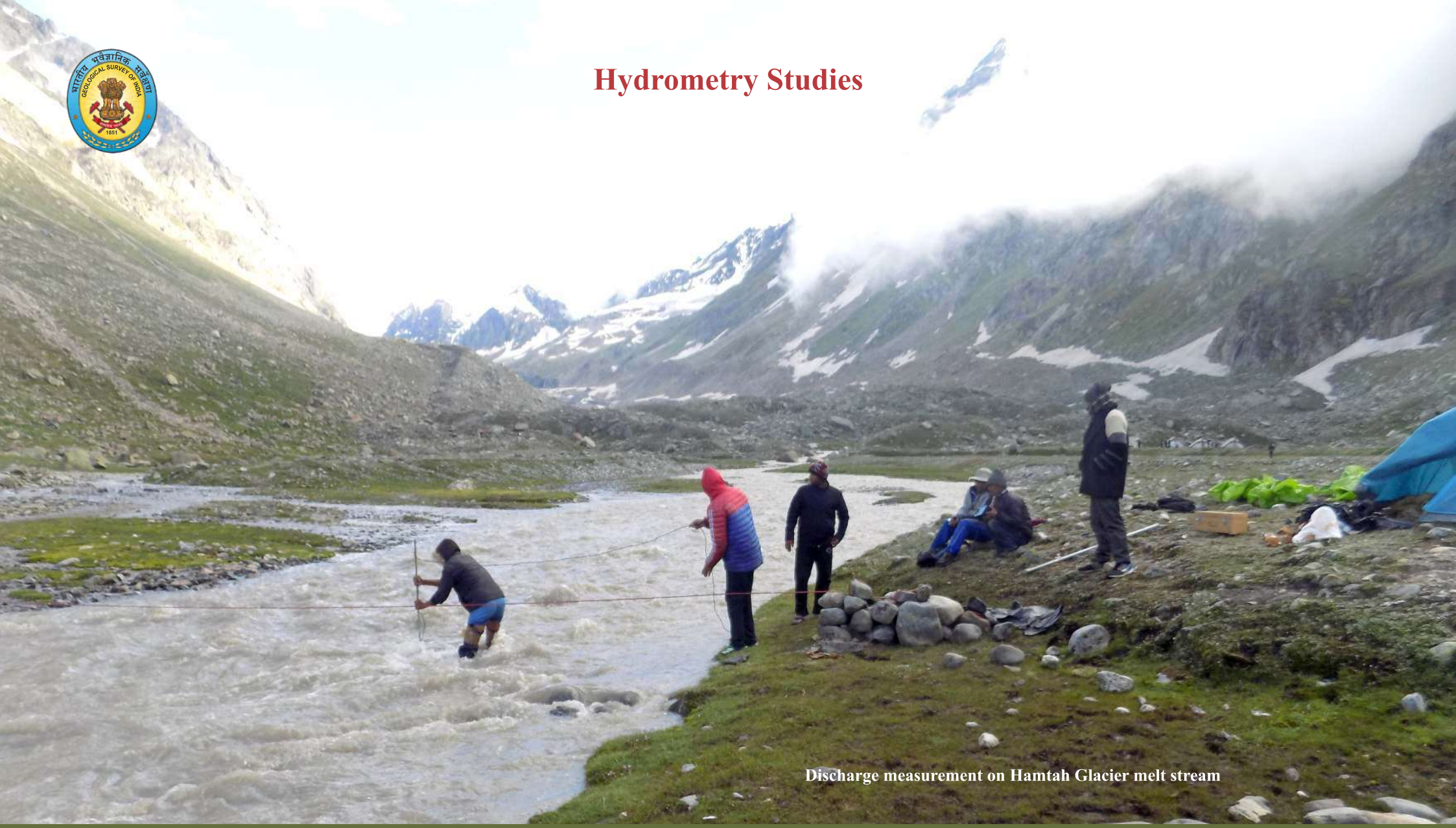
Ablation zone of Hamtah Glacier, where mass balance studies are carried since 1999 and proposed to continue upto 2023. (Photo credit : Saurabh Kumar Rastogi, 2019)

(a) Gara Glacier in 1979 (Photo Credit: M.K. Kaul) **and (b) Gara Glacier in 2011** (Photo Credit: Om Prakash)
(c) Shaune Garang Glacier, Kinnaur District, Himachal Pradesh in 1982 (Photo Credit: R.K. Singh);
(d) Shaune Garang Glacier, Kinnaur District, Himachal Pradesh in 2011 (Photo Credit: Om Prakash)

Accumulation and ablation zone of Panchi *Nala-I* Glacier
(Photo Credit : Pawan Kumar, 2019)

Accumulation zone of Durung Drung Glacier
(Photo Credit : Kalyan Krishna, 2015)

Hydrometry Studies



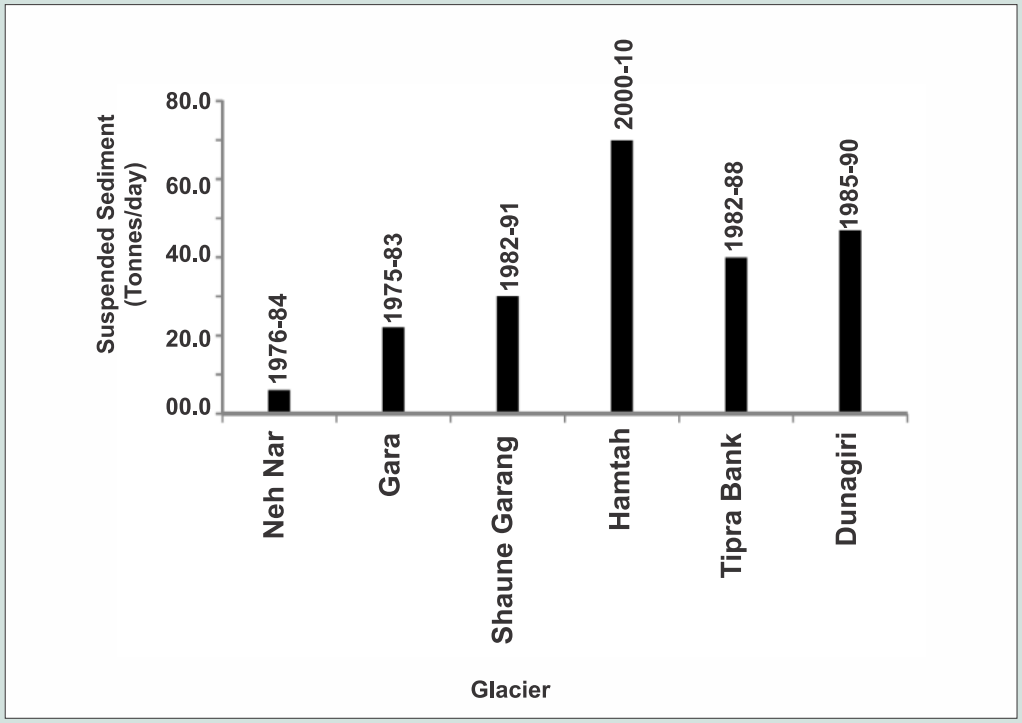
Discharge measurement on Hamtah Glacier melt stream

Hydrometry and suspended sediment transport studies were undertaken along with the glacier mass balance and ablation measurement on Neh Nar, Rulung, Gara, Gor Garang, Shaune Garang, Hamtah, Tipra Bank, Dunagiri and Changme Khangpu Glacier melt streams.

The average daily discharge of Neh Nar, Rulung, Gara, Gor Garang, Shaune Garang, Hamtah, Tipra Bank and Dunagiri Glacier streams were found to be 0.10, 0.019, 0.12, 0.06, 0.41, 0.22, 0.67 and 0.20 ($x10^6 m^3$) respectively.

Suspended Sediment Transport

Himalayan streams emerging from glaciers generally have considerable quantity of suspended sediment. The average suspended sediment load during the period of investigation in Neh Nar, Gara, Shaune Garang, Hamtah, Tipra Bank, and Dunagiri glaciers streams was of the order of 06, 22, 30, 70, 40 and 47 tonnes per day, respectively.



Average daily suspended sediment transported in Himalayan Glacier streams.

Field activities during glaciological expedition

(a) Snout of Bara Shigri Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: E.H. Pascoe, 1906), **(b) Snout of Bara Shigri Glacier, Lahaul & Spiti District, Himachal Pradesh** (Photo Credit: G.N. Dutt 1959)**, (c) Snout of Bara Shigri Glacier, Lahaul & Spiti District, Himachal Pradesh** (Photo Credit: C.V. Sangewar, 1995), **(d) Snout of Bara Shigri Glacier, Lahaul & Spiti District, Himachal Pradesh** (Photo Credit: Zahid Majeed, 2015)

(a) Siachen Glacier, Leh District, Ladakh (Photo Credit: V. K. Raina, 1957)**, (b & c) Siachen Glacier, Leh District, Ladakh** (Photo Credit: C.V. Sangewar, 1985)

(a) Snout of Machoi Glacier, Kargil District, Ladakh (Photo Credits: Oldham, 1904), **(b) Snout of Machoi Glacier, Kargil District, Ladakh** (Photo Credit: V.K. Raina, 1957)**;**
(c) Snout of Sona Pani Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: H. Walker, 1906) **and (d) Snout of Sona Pani Glacier, Lahaul & Spiti District, Himachal Pradesh** (Photo Credit: T.K. Kurien & M.M. Munshi, 1959)

Snout of Gangstang Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: S.P. Shukla, 2008)

Gangstang Glacier has shown a recession of the order of 1335m (between 1963 and 2008). In 2008, it was found that one of the tributaries of the glacier has separated (Gangstang-II) and has developed an independent snout.

Accumulation zone of Hamtah Glacier, Himachal Pradesh
(Photo Credit : Suhrit Pramanik, 2014)

Snout of Yoche Lungpa Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: S.P. Shukla, 2006)

Snout of Tingal Goh Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: Om Prakash, 2008)

Snout of Panchi *Nala*-I Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: S.P. Shukla, 2007)

Panchi *Nala*-II Glacier, Lahaul & Spiti District, Himachal Pradesh (Photo Credit: S.P. Shukla, 2007)

Snout of Miyar Glacier, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Kalyan Krishna, 2015)

Snout of Parang Glacier, Spiti Valley, Himachal Pradesh
(Photo Credit : Arun Chaturvedi, 2013)

(A) Snout of Jobri Glacier, Kullu District, Himachal Pradesh (Photo Credit: Alok Chitranshi, 2003)**, retreated 100m during 1963-2003. (B) Snout of Beas *Kund* Glacier, Kullu District, Himachal Pradesh** (Photo Credit: Alok Chitranshi, 2003) **recession of 750m between 1963 and 2003. (C) Snout of Sara Umga Glacier, Parvati Valley, Kullu District, Himachal Pradesh** (Photo Credit: Alok Chitranshi, 2004) **recession of 1700m during 1963-2004. (D) Snout of Man Talai Glacier, Parvati Valley, Kullu District, Himachal Pradesh** (Photo Credit: Alok Chitranshi, 2004) **recession of the order of 350m between 1989 and 2004.**

Snout of Samundar Tapu Glacier, Chandra Valley, Lahaul & Spiti District of Himachal Pradesh has been retreated by 1266 m at an average rate of 24.82 m/y from 1962-2013. (Photo Credit: Pawan Kumar, 2014)**.**

(a) Snout of Milam Glacier, Pithoragarh District, Uttarakhand (Photo Credit: Cotter,1906), **(b) Snout of Milam Glacier, Pithoragarh District, Uttarakhand.** (Photo Credit: S.P. Shukla, 1997), **(c) Snout of Milam Glacier, Pithoragarh District, Uttarakhand** (Photo Credit: Rakesh Mishra, 2011)

Burphu Glacier has shown continuous recession. During 2011 it was found that the lower part of the ablation zone of the glacier has been detached and the glacier has become hanging with three independent snouts. During 1963-2011 period the glacier has retreated by 3344 m. Three independent snouts of Burphu Glacier, Pithoragarh District, Uttarakhand (Photo Credit :Rakesh Mishra, 2011).

Poting Glacier has shown continuous recession. During 2011 it was found that the lower part of the ablation zone of the glacier has been detached rendering it to become a hanging glacier. During 1963-2011 period, the glacier has retreated by 1393.4 m. (b) Snout of Poting Glacier, Pithoragarh District, Uttarakhand (Photo Credit: B.L. Jangpangi, 1957); (c) Snout of Poting Glacier, Pithoragarh District, Uttarakhand (Photo Credit: Muneer A. Mukhtar, 2011).

Pensilungpa Glacier has shown a total retreat of 394.35m with average annual retreat by 7.44m/y from 1962-2015 period. Snout of Pensilungpa Glacier, Zanskar Valley, Kargil District Ladakh (Photo credit : Pawan Kumar, 2015)

Snout of Meola Glacier, Pithoragarh District, Uttarakhand has shown continuous retreat since 1912. The average annual retreat of the glacier during different periods, *i.e.*, 1912-61, 1961-78, 1978-2000 and 2000-2012 was found to be 7.14, 44.12, 27.27 and 13.33m respectively. (Photo Credit: Om Prakash, 2012)

Snout of Jhulang (Kharsa) Glacier, Pithoragarh District, Uttarakhand has shown continuous retreat since 1912. The annual average retreat of the glacier during 1912-2000 and 2000-2012 was observed at 10.53 and 4.50m respectively. It has also been observed during 2000-2004 period, the middle portion of the snout has advanced by 34m.
(Photo Credit: Om Prakash, 2012)

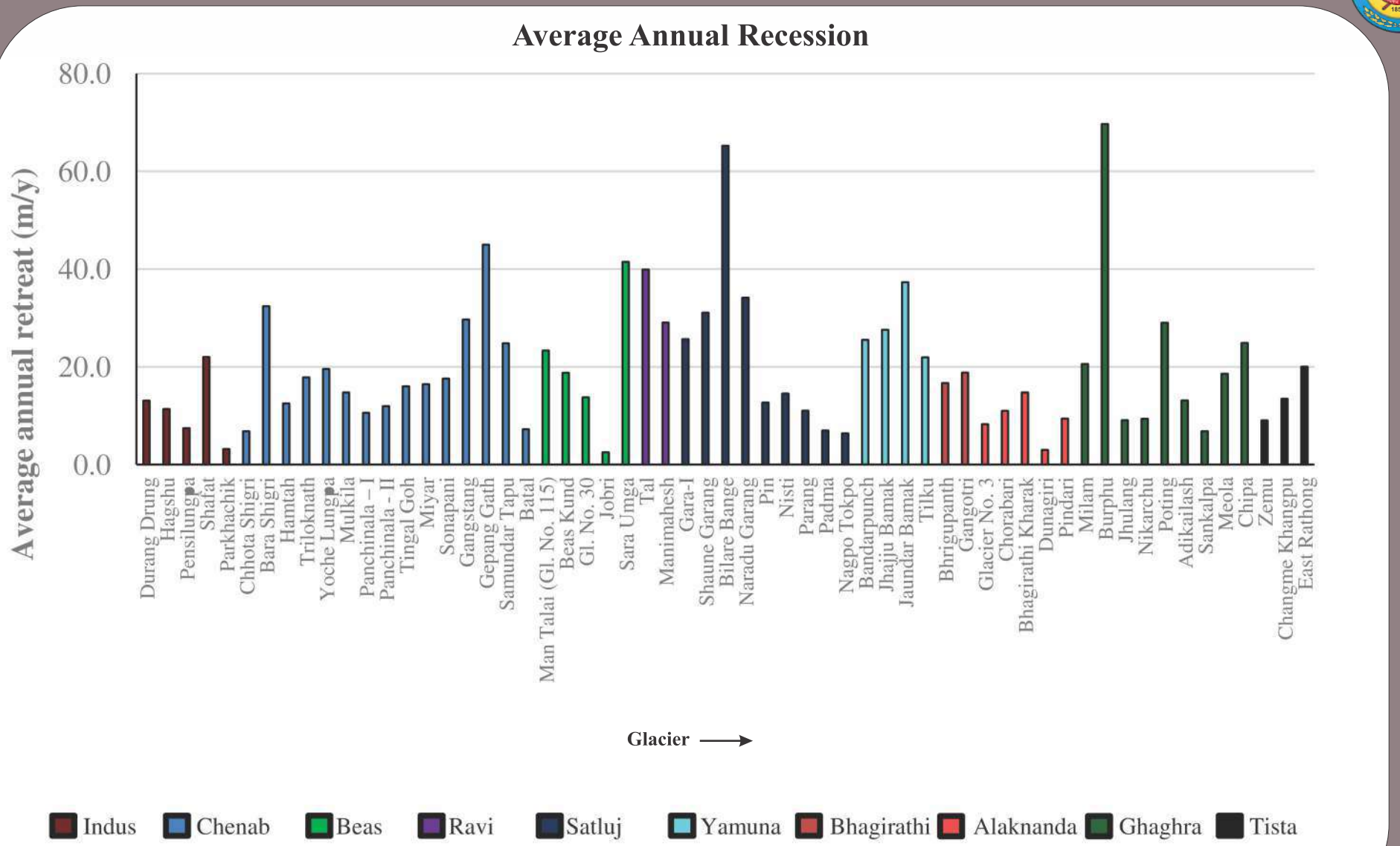
(a) Snout of Bundar Punch Glacier, Uttarkashi District, Uttarakhand retreat of 995m between 1960 and 1999. (Photo Credit: S.P. Shukla. 1999), **(b) Close up of the ice cave of Jaundar Bamak Glacier, Uttarkashi District, Uttarakhand retreat of 1455 m between 1960 and 1999.** (Photo Credit: S.P. Shukla,1999), **(c) Snout of Tilku Glacier, Uttarkashi District, Uttarakhand retreat of 855m during 1960-1999 period** (Photo Credit: M.A. Siddiqui, 1999), **(d) Snout of Jhajju Bamak Glacier, Uttarkashi District, Uttarakhand, retreat of 1075m, during 1960-1999 period.** (Photo Credit: S.P. Shukla, 1999)

Accumulation zone of Chhatru Glacier,
Lahaul & Spiti District of Himachal Pradesh
(Photo Credit : Rakesh Mishra, 2018)

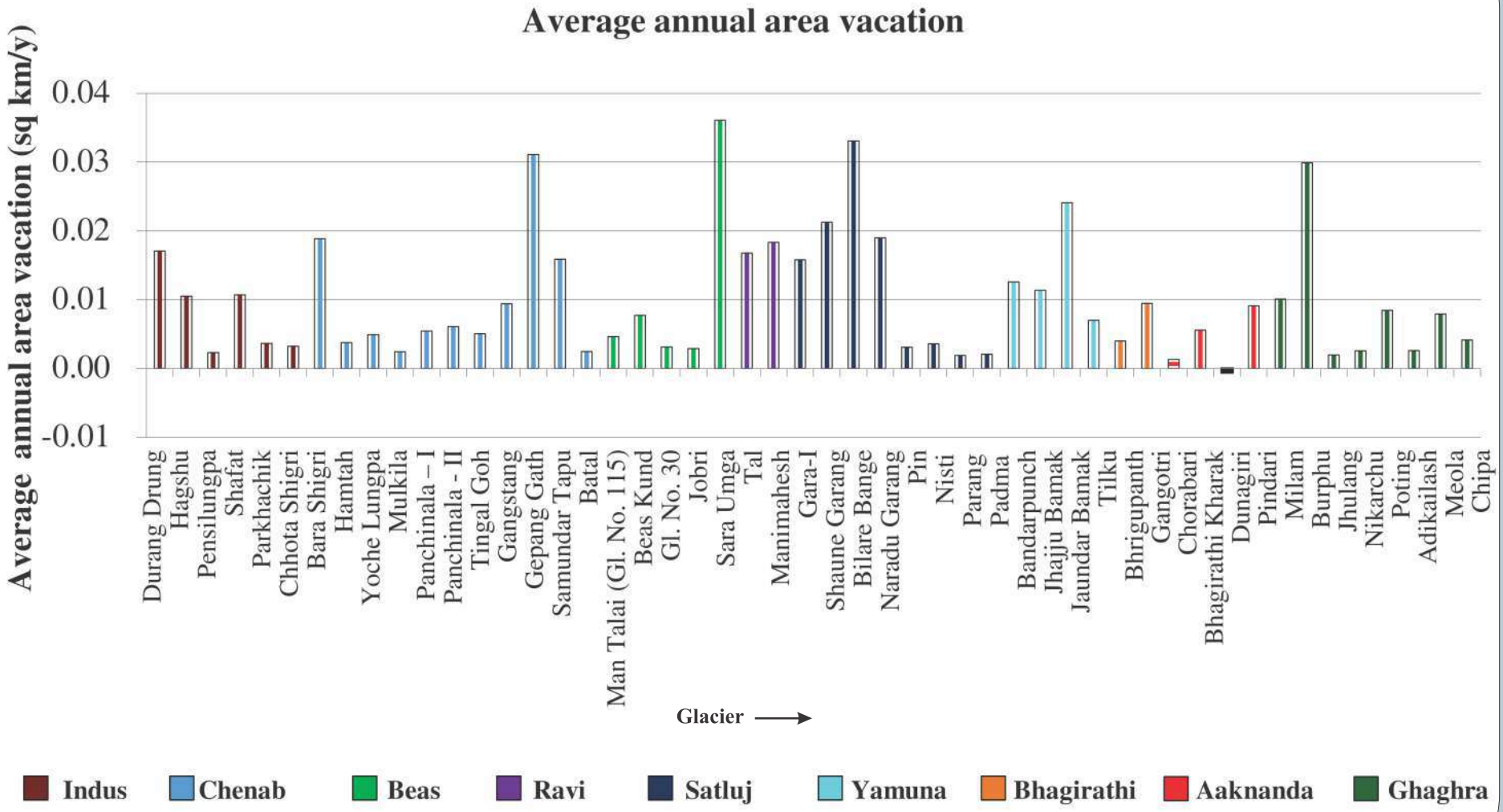
(a) Snout of Pindari Glacier, Almora District, Uttarakhand has shown a total retreat of 405m between 1958 and 2001, Pindari glacier (Photo Credit: L.K. Oberoi, 2001),
(b) Bhagirathi Kharak Glacier, Chamoli District, Uttarakhand has shown a retreat of 575m between 1962 and 2001 (Photo Credit: L.K. Oberoi, 2001),
(c) Jobri Glacier Valley, Kullu District of Himachal Pradesh, 2019 (Photo Credit: Pawan Kumar, 2019).

Ablation zone and lateral moraines of Changme Khangpu Glacier, Sikkim (Photo Credit: Murali Mohan, 2012)

Supra-glacial moraine near the snout of Changme Khangpu Glacier, Sikkim
(Photo Credit: Thrideep Kumar N., 2012)



Average annual snout retreat of the glaciers monitored by GSI in Indian Himalaya.



Average annual area vacation of the glaciers monitored by GSI in Indian Himalaya.

Societal and Other Studies

- Geomorphology and Palaeo-glaciation
- Glacier Depth Assessment
- Lichenometry Studies
- Avalanche Assessment Studies
- Glacier Lake Outburst Floods
- HRD & Data Dissemination

Samundra Tapu Glacier, Chandra Valley, Lahaul & Spiti District, Himachal Pradesh
(Photo Credit: Arun Chaturvedi, 2015)

Glacial ice sampling, Miyar Valley, Lahaul & Spiti District, Himachal Pradesh.
(Photo Credit: Saurabh Kumar Rastogi, 2018)

Water sample collection, Miyar Glacier, Lahaul & Spiti District, Himachal Pradesh.
(Photo Credit: Pawan Kumar, 2018)

OSL sample collection, Miyar Valley, Lahaul & Spiti District, Himachal Pradesh.
(Photo Credit: Pawan Kumar, 2018)

OSL sample collection, Sagtogpa East Glacier, Ladakh.
(Photo Credit: Muneer, A. Mukhtar, 2018)

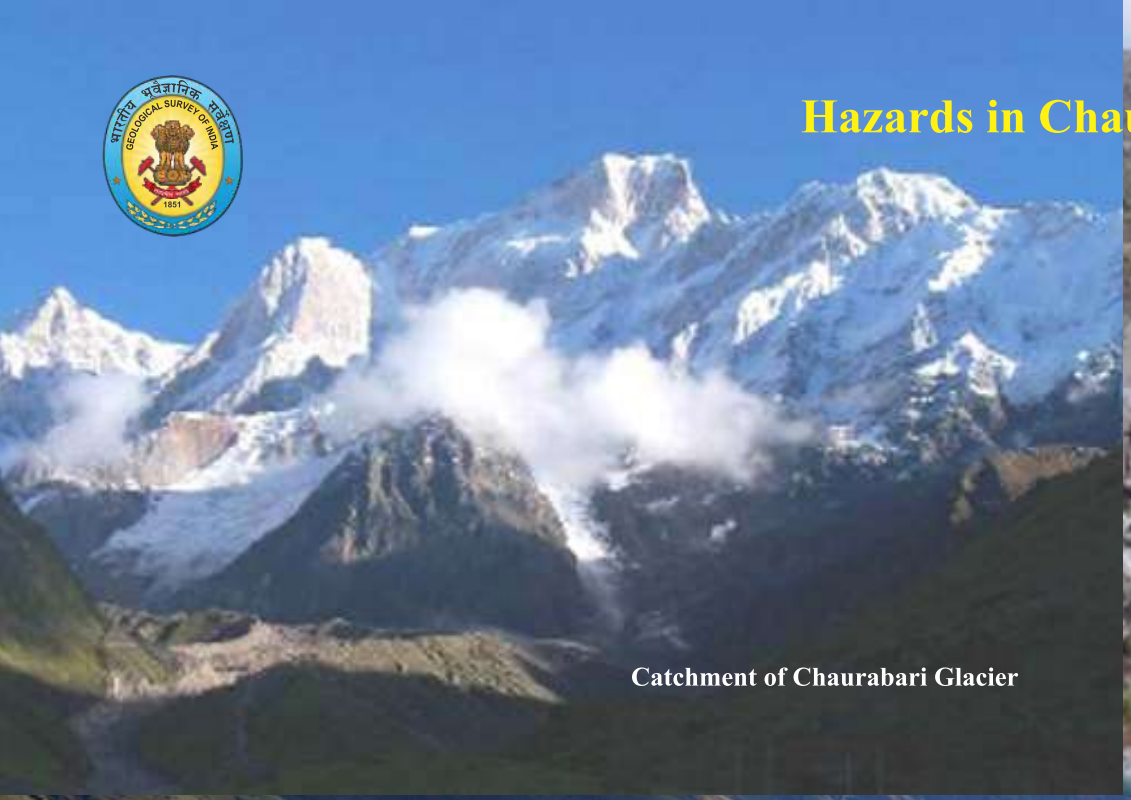
Lichenometry Studies

- Lichenometry studies were undertaken on Gara, Gangotri, Gor Garang and Neh Nar glaciers for estimation of absolute/ relative age of the moraines.
- In Gangotri area studied lichen species were *Xanthoria elegans*, *Rhizocarpon sublucidum* and *Rinodina oreina*.
- The dates for other three moraines were deduced as 1865 A.D., 1849 A.D. and 1782 A.D.
- The moraines of Gara and Gor Garang glaciers were classified based on the size-antiquity relationship.

Glacier Depth Assessment Using GPR

Ground Penetrating Radar (GPR) survey by GSI officers at Hamtah Glacier.
(Photo Credit: Arun Chaturvedi , 2012)

Hazards in Chaurabari Glacier

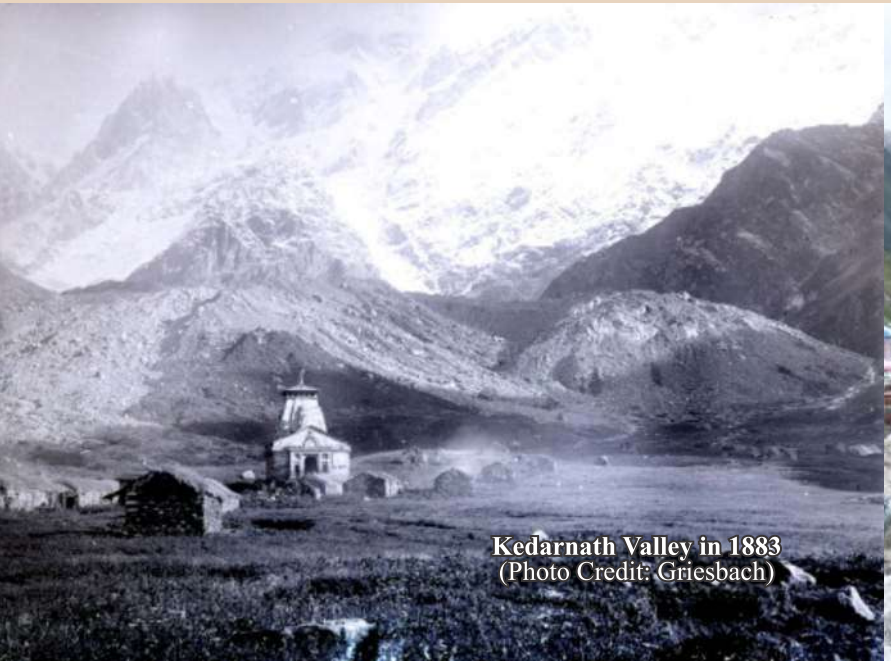


Catchment of Chaurabari Glacier

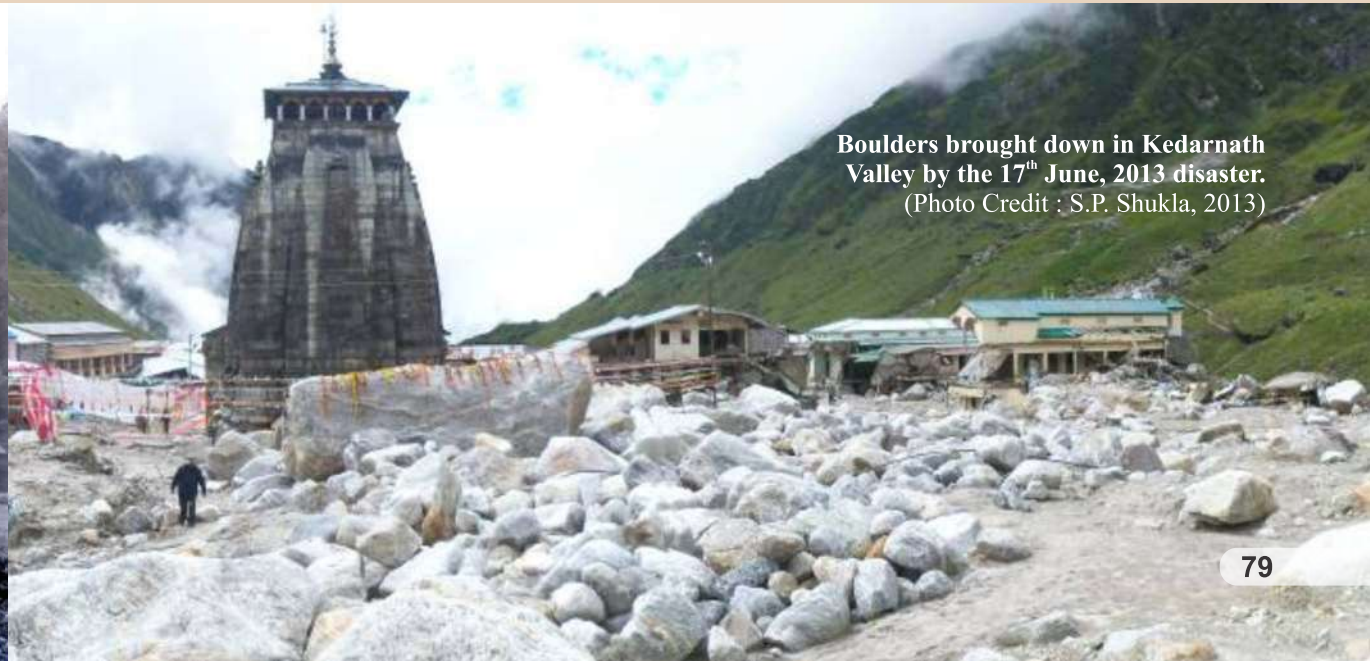
Snout of Chaurabari Glacier,
Rudraprayag District, Uttarakhand

Kedarnath Valley, downstream of the Chaurbari Glacier, Rudraprayag District, Uttarakhand. Kedarnath township was devastated in 2013 due to incessant rain followed by bursting of moraine dammed lake. (Photo Credit: Zahid Majeed, 2010)

Moraine dammed Gandhi Lake which breached in 2013 leading to heavy devastation in Kedarnath Township,
(a- Photo Credit: Deepak Srivastava,1994 and b- S.P. Shukla, 2013)



Kedarnath Valley in 1883
(Photo Credit: Griesbach)



Boulders brought down in Kedarnath Valley by the 17th June, 2013 disaster.
(Photo Credit : S.P. Shukla, 2013)

Glacial Lake Outburst Floods (GLOF) are considered as one of the worst disasters. In Himalayan region there are several large pro-glacial lakes. Gepang Gath in Himachal Pradesh has a large and expanding pro-glacial lake and the glacier snout is calving into the lake. Inset Map shows recession of Gepang Gath Galcier with time.
(Photo Credit: Muneer Ahmad Mukhtar, 2012)

Vasudhara Tal, Chamoli District, Uttrakhand
(Photo Credit : Pawan Kumar, 2016)

Mabang Proglacial Lake, Pithoragarh District, Uttarakhand
(Photo Credit: Pawan Kumar, 2017)

Debris flow near Chaling, Miyar Valley, Lahaul & Spiti District, Himachal Pradesh. (Photo Credit: Saurabh Kumar Rastogi, 2017)

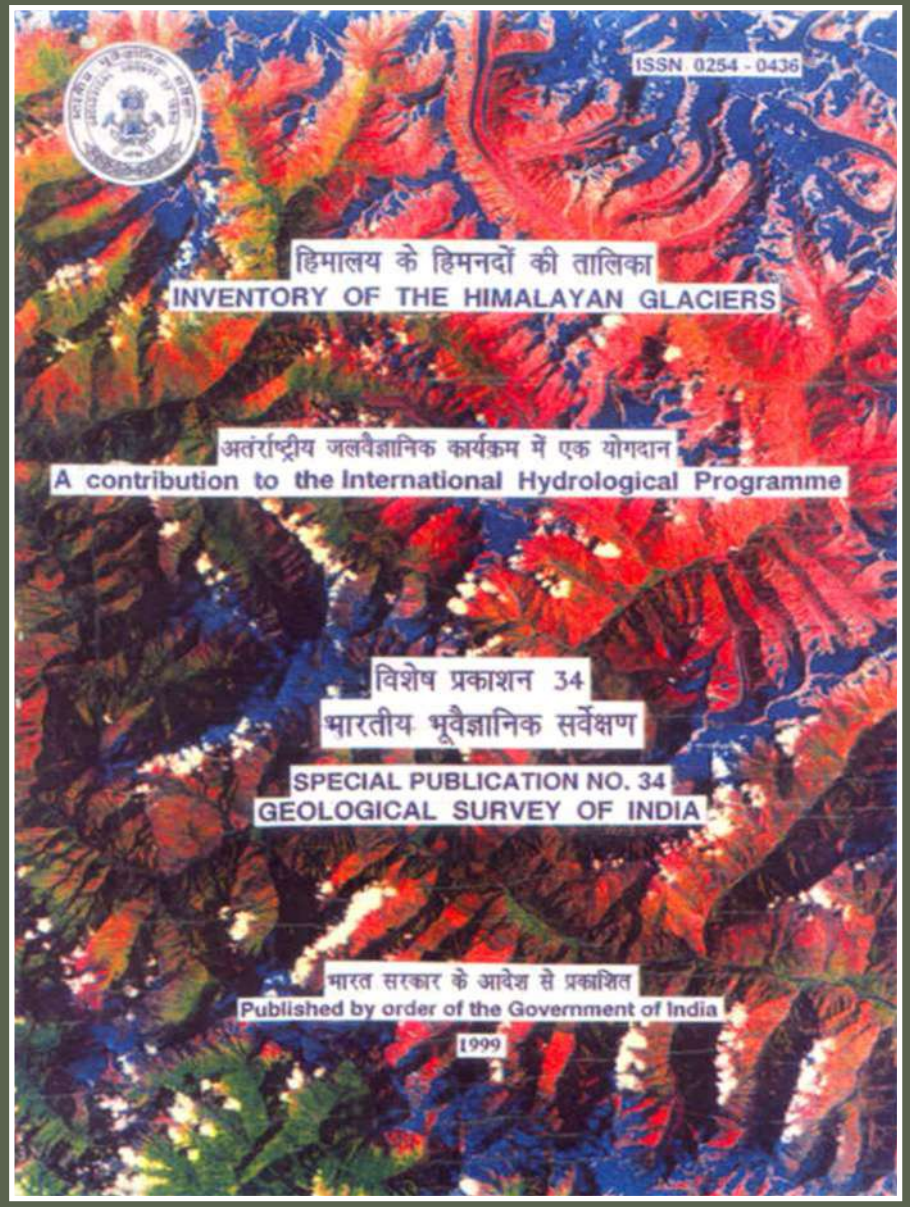
South Lhonak Lake and glacier bounded by moraines.
(Photo Credit: Gyaneshwar Singh & Lalit Mohan, 2018)

Close up of the recessional moraine of South Lhonak Lake.
(Photo Credit: Gyaneshwar Singh & Lalit Mohan, 2018)

HRD & Data Dissemination

Training Institute, GSI has conducted nine training courses between 1993 and 2017 wherein 148 scientists belonging to various national organisations and universities were trained.

Data Dissemination : Publications by GSI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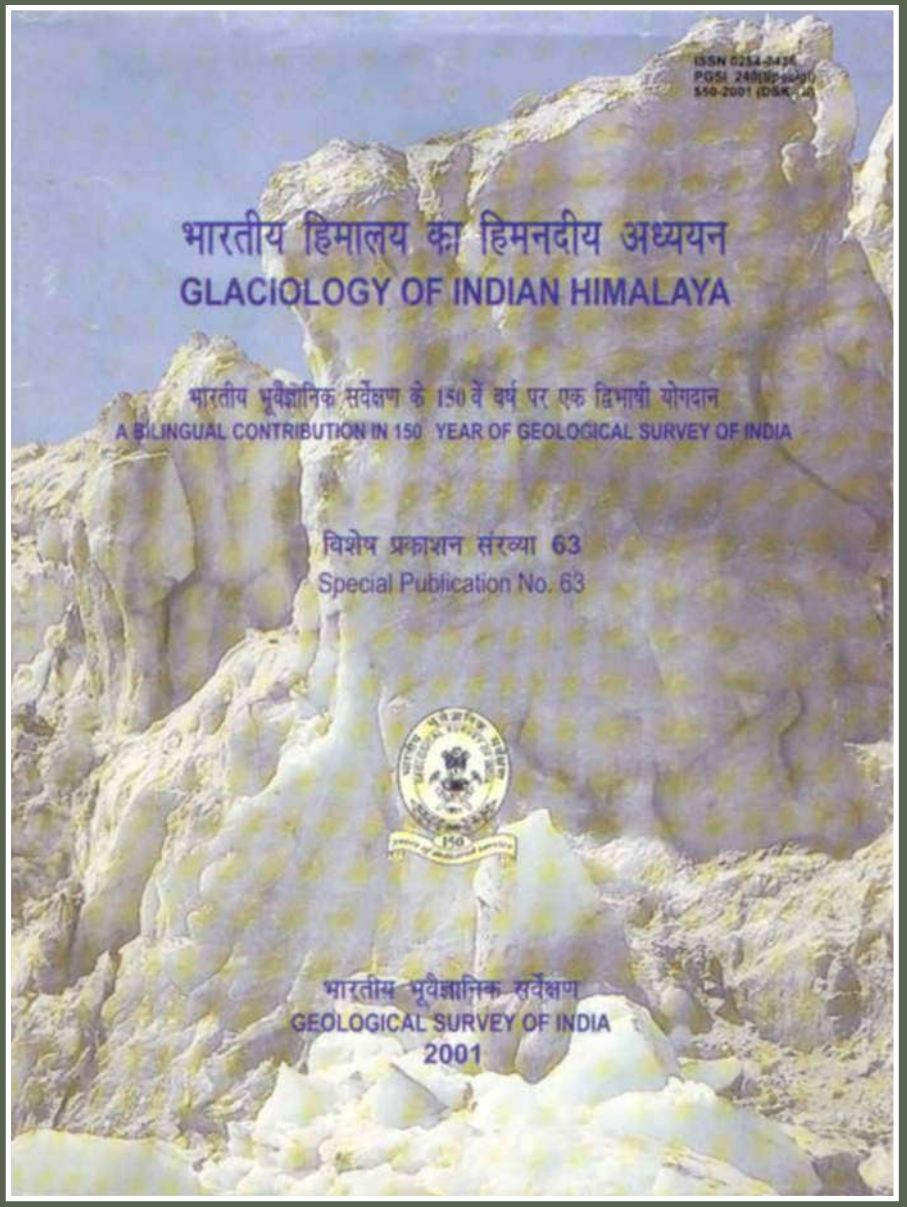
Published by order of the Government of India
1999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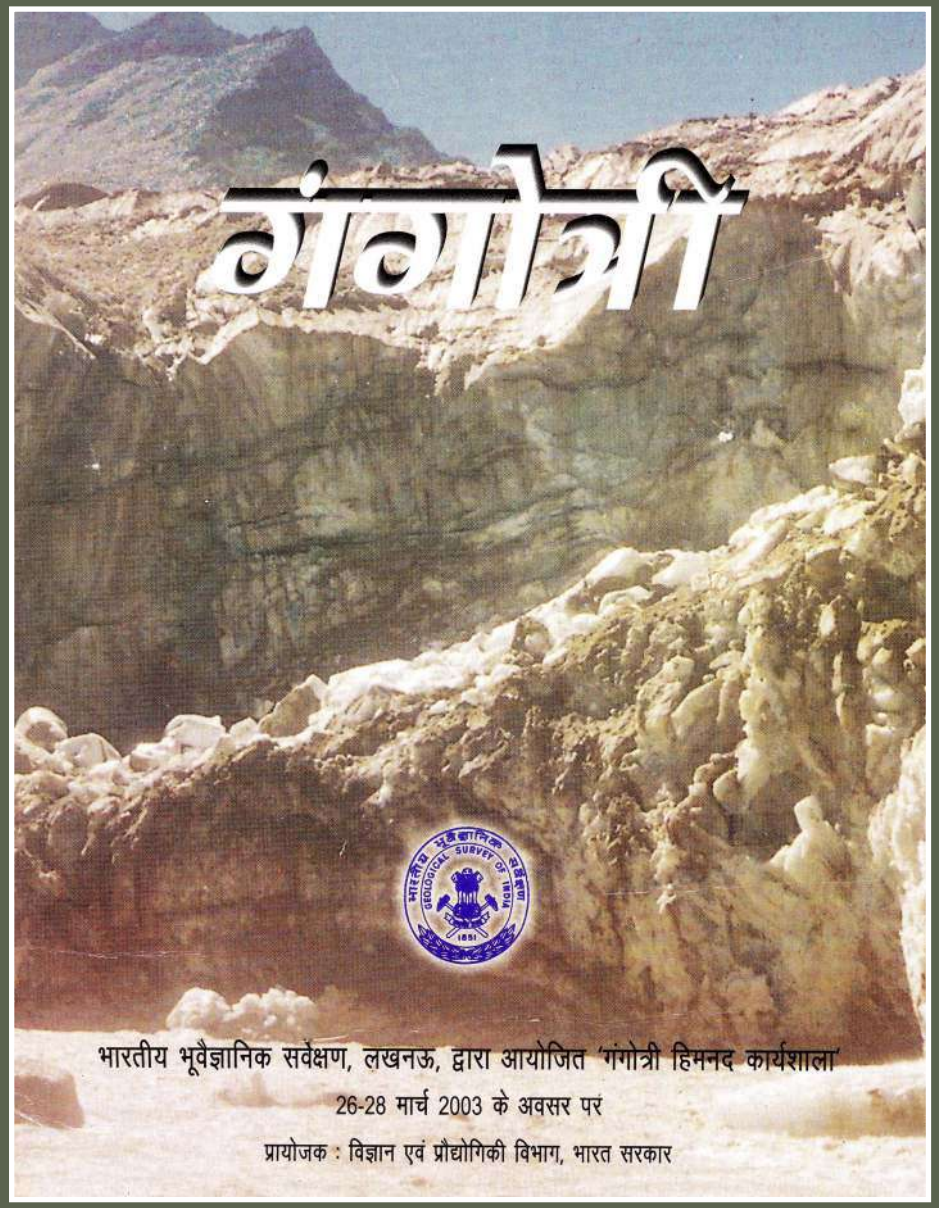
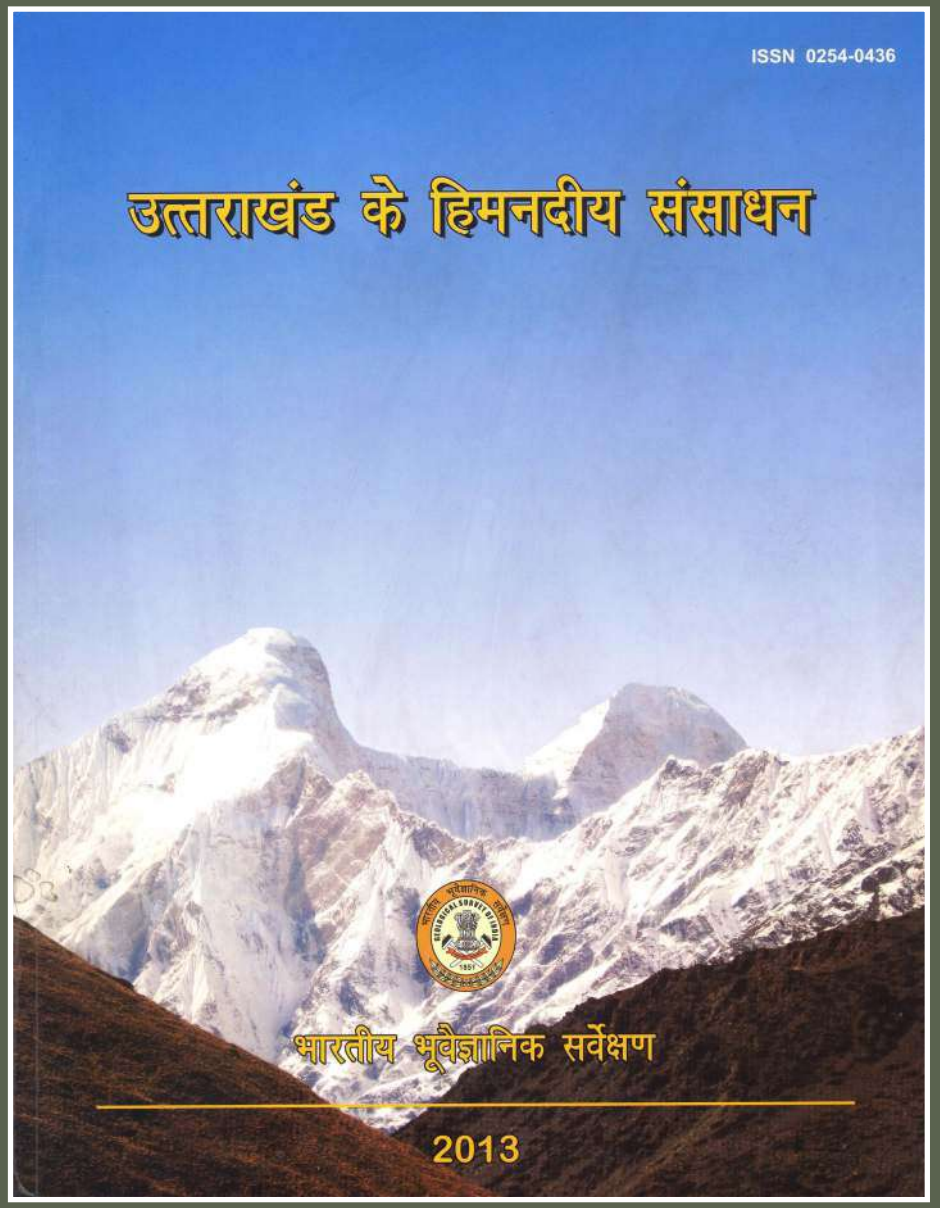
Data Dissemination : Publications by GSI





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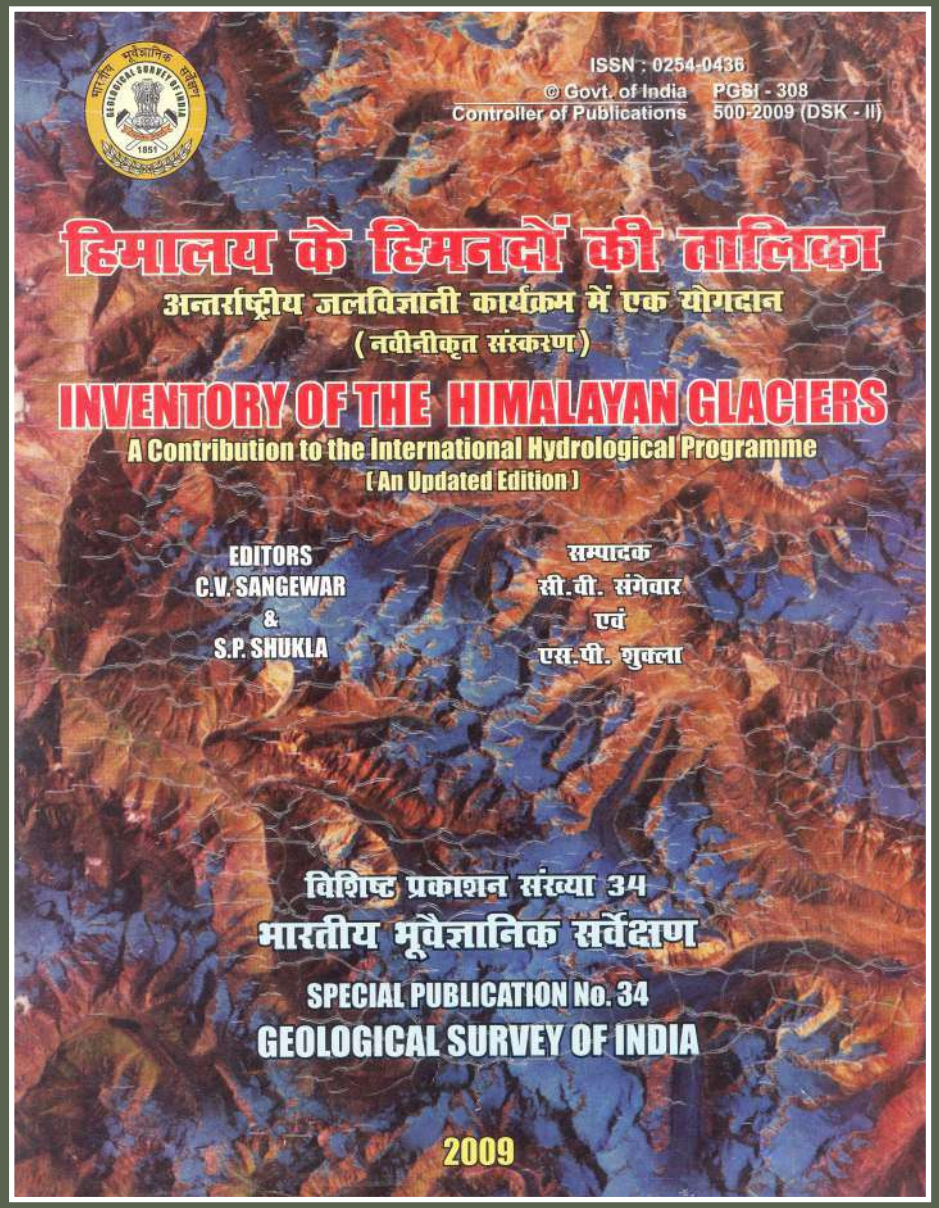

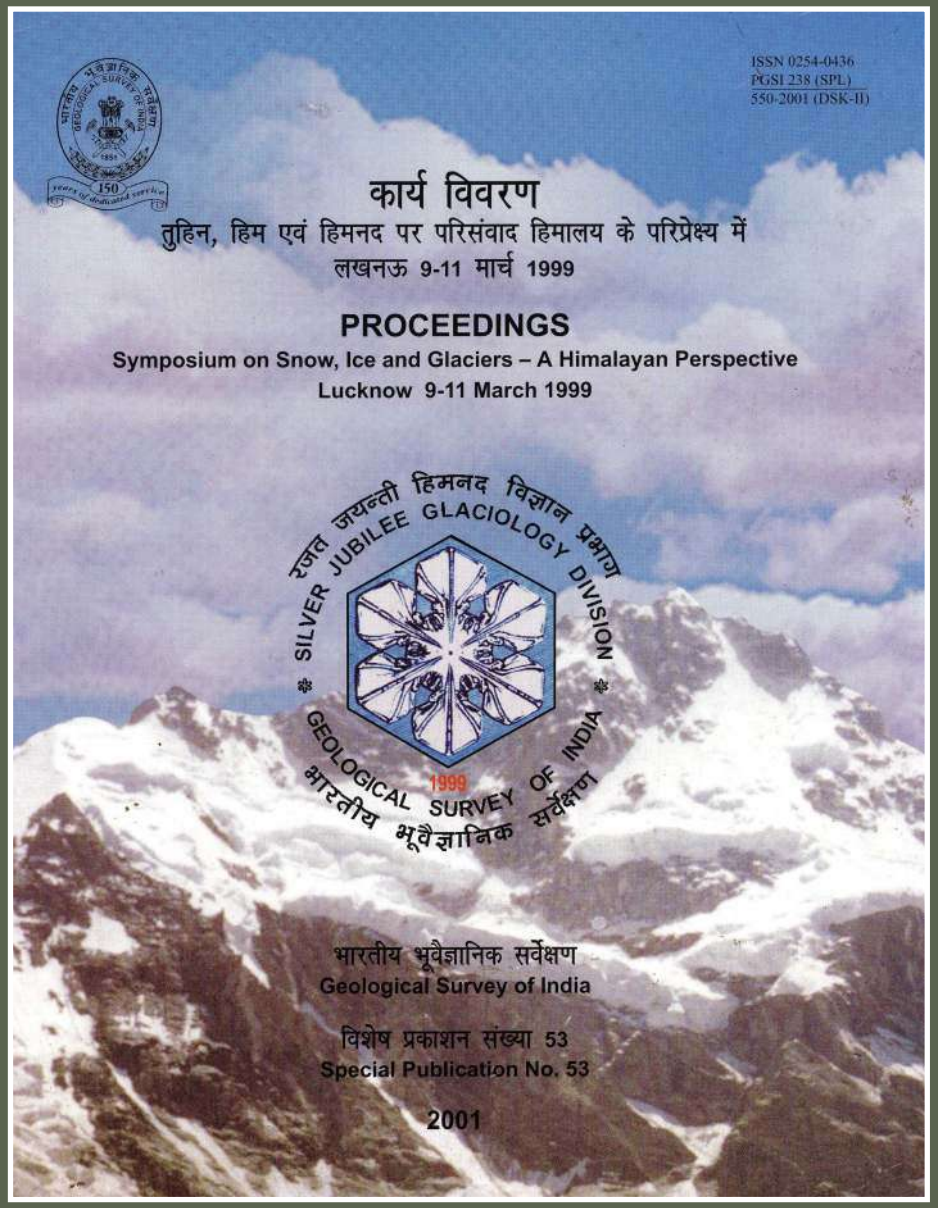

About the Authors

***Dr. Rajesh Asthana**, Dy. Director General, GSI, NR, Lucknow is an Antarctic Veteran who has participated in 8 Antarctic expeditions to conduct geological and glaciological investigations under one of the most hostile and challenging working condition. He was the Expedition Leader in 24th ISEA and Voyage Leader in 3 expeditions. He had participated in Triloknath Glacier Expedition in Himachal Pradesh during 1995 and was responsible in organizing a DST sponsored field based training programme in glaciology during his brief stint of about one year in 2017 as the Director, Glaciology Division. So far, he has published 12 research papers in international journals and 22 in national journals and book chapters. For his contributions in the field of expedition based glaciological and geological investigations, he has been conferred National Geoscience Award in 2012.*

***Dr. Satya Prakash Shukla**, Director, Polar Studies Division has over two decades of experience in Himalayan Glaciology and has carried out extensive work on glaciers of Himachal Pradesh, Uttarakhand, Jammu & Kashmir and Sikkim. In addition, he has also worked on glaciers of Arctic Region. He has organized, nationally acclaimed DST sponsored Field Training Courses in Glaciology. He has edited 'Inventory of Himalayan Glaciers' an updated edition, 2009 and 'Uttarakhand ke Himnadiya Sansadhan' in Hindi.*

***Shri Rakesh Mishra**, Superintending Geologist, Glaciology Division has two decades of experience in the field of coastal geomorphology, environmental geology, Quaternary geology and glaciology. He is mainly engaged in glaciological studies in Himalayan and Arctic Region with various aspects including mass balance, secular movement studies and associated specialized studies related to societal issues. He has participated in three Scientific Expeditions to Arctic Region consecutively. He had contributed significant scientific papers at international and national journals.*

***Shri Kalyan Krishna**, Senior Geologist has joined in GSI on 1st April 2010. He has been active in the field of marine science, coastal geomorphology, environmental geology and subsequently in glaciological studies since 2015. He has extensively worked on the glaciers of Uttarakhand, Himachal Pradesh and Jammu & Kashmir involving various aspects like mass balance, secular movement and micro-climatic studies and geochronology. So far, he has led four glaciological expeditions and investigated more than 17 glaciers besides the integration of application of remote sensing and field observations.*

View of Pir Panjal Range
(Photo Credit : Pawan Kumar, 2019)

Contact us:
Addl. Director General & HOD
Geological Survey of India
Northern Region, Sector-E, Aliganj,
Lucknow-226024
E-mail: hod.nr@gsi.gov.in
website: www.gsi.gov.in
Phone : 0522-2378796; Fax : 0522-2336079